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SCIENTIFIC FACT AND SCIENTIFIC INFERENCE.

BY H. W. CONN, PH.D.

IT is the custom of scientists to regard their contributions to knowledge as the only ones concerning which there is any certainty. They point with pride to the many steps in advance taken by natural science within the last few centuries, and would compare this advance with what seems to them the stationary condition of non-scientific thought. The advances of science are thought to be sure, requiring no retracing, while non-scientific thought can be certain of nothing, one generation pulling down the structure of the last, only to put in its place an equally unstable conception. Metaphysics has scarcely reached a more certain position than it has held for centuries, for we still find schools and schools of metaphysics, each of which takes an entirely different view of nature. Theology is still divided into numerous beliefs, each bitterly opposed to the others. What little advance has been made our scientists think has been brought about through their discoveries, and they sometimes challenge the production of any positive advance in knowledge which has not been made through the instrumentality of science. Science, then, claims to be the only sure realm of knowledge, and claims that its truths, once established, are established for eternity. The scientific method has indeed been defined as one which accepts nothing without proof, in contradistinction to the unscientific method, which is willing to accept entire many theories and beliefs for which there is no proof and the meaning of which is unclear.

Now, nothing is more plain than that science does *not* confine itself to demonstrated truth. It is easy to find in scientific publications hundreds of theories which have been advanced, defended, disputed, and rejected. Scientific literature is to-day filled with speculations and theories which are no more demonstrated than the most unreliable of non-scientific theories. Scarcely a publication appears that does not contain some new speculation, so that science is burdened with hundreds of unproved, unprovable hypotheses, making it as difficult sometimes to discover accepted truth of scientific teaching as to discover the accepted truth of those lines of thought which we call non-scientific. Yet in spite of this coming and going of hypotheses, or rather, as we shall see later, on account of it, the claim is still that science is the only sure thing, and its conclusions are the only ones that cannot be gainsaid. We find it almost universally recognized, not only among scientists, but among all thinking men, that if a universally-accepted scientific conclusion comes in conflict with any other, it is the scientific conclusion which stands and eventually modifies the other. If this authority for scientific facts is both consciously and unconsciously recognized, it must rest upon some foundation.

Absolute knowledge is, of course, impossible. No matter what we observe or prove, it is always open to the agnostic to deny all knowledge. We can never be certain that our minds are not utterly deceiving us, and that our mental processes are not in contradistinction to reality. We can never prove that the universe is intelligible, nor can we prove that the fact of our minds compelling us to assume nature to act in certain ways shows that nature does act in these ways. It is, of course, useless to attempt to demonstrate the truthfulness of nature or mind; and for this reason scientific observations and conclusions are open to doubt as well as all others. Fundamentally, no one thing is more certain than another, because a question as to the validity of thought affects everything alike. No advance is possible without the fundamental assumption of the truth of mind and nature. We must, then, always start with this assumption, and the question we are to consider becomes this: Assuming the truthfulness of mind and nature, are the conclusions which we call scientific any more likely to be correct than those which we call non-scientific? That they are almost universally so

regarded is certainly true. Let us, then, endeavor to find out upon what this claim for superiority rests.

It is frequently said that science's claim for authority is due to its dealing only with facts; but plainly this statement is far from expressing the truth. For, in the first place, all realms of knowledge deal with facts of some sort,—though facts relating to mind may be less cogent than those relating to physical nature,—and, in the second place, science is more than a collection of facts. A process of collecting and narrating facts is not science, for facts have no meaning except as they are compared together, and as conclusions are drawn from them. The significance of science, then, rests upon the deductions from the facts, and not upon the facts themselves. We must therefore carefully distinguish between scientific facts and scientific inference, and consider each in turn.

By scientific facts we mean simple matters of observation, such as that a given stone drops to the ground. In regard to them there can be no doubt that they are everywhere regarded as the most certain factors of knowledge. This certainty seems to rest upon two things,—Firstly, scientific facts themselves are of such a character that they cannot be modified by man nor changed by his imagination. They are beyond the reach of human influence, and we are forced to accept them as true. Now, this cannot be said of the data of other realms of knowledge. We clearly recognize that minds are unlike, and that people think very differently upon the same subject. Some men even deny that there is a right and wrong, or would change the word right for expediency. When a subject such as metaphysics rests upon the introspection of mind alone, it is evident that the personal factor is a large one. Nothing is, perhaps, more certain than the primary laws of thought, and we must assume that, if freed from personal idiosyncrasies, all minds would think alike. But thinkers have not yet been able thus to free themselves; and when it comes to the application of the laws of thought, either the difficulty of the application or the personal factor of the individual becomes so great that contradictory results are reached and the certainty, of course, destroyed. We see from this that mind is open to error, which must be recognized as affecting all but the simplest laws of thought. Mental processes, mental perceptions, mental activities in general, are open to vari-

ation in different persons; but we are confident that the facts of nature are alike for every one, and are therefore more to be trusted than anything open to individual variation. But, secondly and primarily, the certainty of scientific facts rests upon the recognition that they need not be accepted as matters of evidence simply, but are of such a nature that they can be repeated and again observed. It is possible to perform a scientific experiment as many times as desired, and with the same results. If any one doubts the results, they can be proved to him by making him observe them. While practically all observations must be given on matters of evidence, nothing rests ultimately upon evidence, for there is always the possibility of repetition and verification. Upon this consideration rests primarily our confidence in the facts of science; and this, again, is a source of certainty not possible except in natural science. History approaches more closely to science in its certainty than anything else. A scientific fact is in itself, of course, no more sure than a fact of history, in so far as each rests upon the same evidence, and the evidence may become sufficient to establish historical facts with absolutely convincing force. But we can never repeat facts of history; it must depend entirely upon evidence, which becomes less certain as it becomes less in amount, and consequently as we get farther away from the facts. Nor can we ever be sure of repeating mental conceptions. We can never know that we are following another person's thoughts, or that we are putting ourselves into the same mental position which he holds. We cannot be certain, then, that we are performing the same mental processes, and therefore repeating his thoughts. In so far, then, as scientific facts depend upon evidence, they have the same force as facts of history. In so far as they imply mental processes in observation, they are open to the same sources of personal error as all other mental actions. But when they can by repetition be made a perpetual source of evidence to each individual, and when we realize that they are matters of observation and not of interpretation, and therefore personal idiosyncrasies are almost entirely eliminated, we must look upon scientific facts as more certain than all others, and, indeed, as approaching the condition of absolute certainty.

But this is only the beginning of the matter. If science contented herself with facts her position would be unassailable, but

worthless. We sometimes hear it said that science should stop with facts, and that it has no right to draw conclusions; but this is plainly both impossible and undesirable. A science made up of facts, no matter how true they might be, would be meaningless. Simple observations, however numerous, no more constitute science than a lot of numbers shaken up in a basket would constitute mathematics. It is only as the facts are classified, as generalizations are made, as inferences are drawn from them, and conclusions reached, that observations begin to have any significance. It is a meaningless fact that the Silurian rocks are under the Devonian, but it becomes pregnant with meaning when we draw the inference that this indicates a relative age of the rocks and fossils in them. It is utterly valueless to us to know that a thousand stones which we have observed fell to the ground, but it is of the utmost importance when we draw from the observations the conclusion that all heavy bodies tend to fall towards the earth, and of even more significance when we conclude that all bodies tend to fall towards each other. In these simple cases the conclusions seem almost included in the observations, but, nevertheless, they are entirely distinct from them; and this serves to illustrate the statement just made, that it is only inferences and conclusions which are of any significance. If, then, science uses its observed facts only as data for inferences, and is itself a collection of deductions, is it any more deserving of credence than other branches of learning? Plainly enough, there is no longer either of the special reasons for acceptance which we have seen giving superior value to scientific facts. The inferences here are just as truly open to the error of the personal equation as they are in any other line of knowledge, and there is primarily no reason for thinking them better drawn in science than elsewhere. Is there, then, any reason for thinking that scientific conclusions are especially deserving of credence, and have a right to the claim which scientists hold for them,—of being the most certain conclusions of knowledge? That the usual answer to this question will be in the affirmative seems quite certain. Scientific conclusions are everywhere received as authoritative. They have driven other branches of learning from many of their positions, and have not in turn been driven. The most serious argument which can be urged against any belief is that it contradicts the conclusions of science, and it

is everywhere recognized that our theological and metaphysical beliefs must agree with the accepted conclusions from science.

But no sweeping statements can be made. Scientific inferences have a very varying degree of probability, ranging from almost certainty to the wildest hypothesis. Proof of an inductive conclusion is an impossibility, for it must not only be shown that the conclusion in question fits all the facts of the past, present, and future, but also that it is the only conclusion that can possibly be framed to fit the facts. This is a manifest impossibility; but the approximation to it may be very close. Most persons would regard the circulation of the blood as a demonstrated fact, and yet it has never been observed nor absolutely demonstrated. It is an inference from observed facts, but an inference so strong that it is utterly impossible to doubt its being the truth. From practical certainty like this we may pass by easy stages to the wildest hypothesis. The law of gravitation; the theory of the long duration of the geological ages; the theory of evolution; the theory of the spontaneous generation of life, either at the present time or in the past; the idea of a central sun around which all the stars in the universe are revolving,—all of these represent inferences from scientific facts, but inferences of a less and less degree of cogency of proof, until the last is nothing more than a poetical speculation. Recognizing thus the varying degree of probability, it is plain enough that it is impossible to make the general statement that scientific conclusions are of any more value than those from non-scientific thought. Nor, indeed, would our scientists pretend that such a statement could be made, for, however firmly they may believe in the cogency of their conclusions, they are fully aware of the possibility of false inferences and mistaken theories.

How is it, then, that scientific conclusions can have any superior authority? The answer is, because they are, in most cases, open to a more or less direct verification, and the force with which they appeal to us is directly proportioned to the exactness of this verification. It is frequently possible, by appealing to facts of observation (which we have seen are our most sure source of information), to render an inference palpably absurd, or to show it in most exact accord with all nature. In the first place, our scientists are constantly dealing with facts. They begin their training by observation, and for a long time observa-

tion occupies almost their sole attention. Many, indeed, get no farther than this, and are little more than observing machines. When they do go outside this line it is always with more or less caution, because they well know that if their inferences be not truths they will soon be disproved. Trained to deal with facts, they are constantly using observation as checks and guides to their speculation, and after any conclusion is reached or any theory made it must meet thousands of unthought-of observations from nature, and be found to fall in with them all in perfect harmony before it can stand as an accepted scientific conclusion. In this they differ from metaphysical or philosophical inferences. If one theologian differs from another, each can think the other mistaken without the possibility of proof, for the necessary facts are beyond their reach, and the different stand-points of the two give, each, a different view. But if one scientist differs from another, it is frequently only a matter of a few years when further collections from nature's store of facts will refute the position of one, or perhaps both. Here, then, there is a possibility of verifying the realm of thought by the realm of fact. Observations are made, and the mind works them over and draws conclusions from them, creating usually a thought to explain them. Then once more it turns to observations to see if the thought created for a few facts will explain all, and thus have the force of a general truth. When Darwin first conceived the theory which afterwards made his name famous, it was from a few observations upon the geographical distribution of animals; but, having conceived a thought which explained these facts, he spent twenty years in patient application of this thought to all other classes of observation, and it was not till he had satisfied himself that the conclusion did harmonize with all the facts which he could collect that he was ready to let it be known. When the theory was finally given to the world its great force was in this very fact, that it was shown to be in such accord with numerous facts of nature; and what prevents it from being universally accepted to-day is that there are still some facts which do not seem in accordance with the theory.

Thus it is with all scientific theories which have any authority. There is always a world of observation to be considered, which must be found in harmony with the conclusions. So cogent do these conclusions sometimes become that they not only enable

us to interpret the present and explain the past, but to predict the future. In every way they may thus be made to show their exact harmony with nature. False inferences cannot be in harmony with this truth, and errors cannot stand. Scientific theories are very abundant, and many of them are wrong, but the world of facts gives an opportunity for examination, dispute, and final rejection of the false ones. This fact, that many theories have been disproved and rejected by those who originally advanced them, is the greatest safeguard of science, for it gives us the greater confidence in such conclusions as retain the universal acceptance of thinkers after long discussion.

In this way it is that scientific conclusions may, under the right conditions, appeal to us with such force. Such a verification is impossible in other branches of learning. There are no similar series of observations which can be brought to testify to the truth of metaphysical or ethical conclusions. Here each conclusion can be attested only by the same sort of evidence which produced it. It is, in all stages, a mental conception, for which there can be no physical evidence. The errors which may have crept into the original inference cannot be removed by contact with reality. The personal equation becomes great, and hopes, desires, loves, and enmities may come in to modify that equation. A person brought up as a Mohammedan believes Mohammedanism beyond dispute, while we are even more confident of the truth of Christian beliefs. Two races of people, if kept separate from each other, might develop different systems of theology, of metaphysics, of art, of morals, because these would depend almost entirely upon the thinker; but the laws of dynamics, the classification of the animal kingdom, would be alike in both cases, for these depend not upon the thinker alone, but are verified by nature.

Assuming, then, the general truthfulness of nature and the validity of mind, there is a general concession that there is a greater certainty possible for scientific inferences than for others. A greater certainty *is possible*, but it does not always exist, nor does it extend to all scientific theories. Because a universally-accepted theory claims so great credence it by no means follows that all science deserves a similar acceptance. Here it is that scientists make their greatest mistake, in failing to separate the positive from the probable and the possible. The conclusion

that the fossils of our rocks were once living animals occupies a very different position from the theory of evolution. One is almost included in the observed facts, while the other implies much more of inference. But too often our writers and teachers fail to separate them, giving equal credence to such theories as the undulatory theory of light and the law of gravitation. This is all very well when scientist is addressing scientist; any amount of imagination and speculation is then admissible. Hypothesis may be assumed as fact, and used as a basis of further conclusion. But a teacher to his students or a writer to the general public should be very careful to distinguish between the positive, the probable, and the possible. He should offer as positive only such conclusions as have placed themselves beyond dispute, and regard all others as more or less probable, according as they have been verified by observation. Unfortunately, many of our teachers, and an even greater number of our writers, fail to do this. They are ready to accept before the public more than is proved, as it is perfectly proper for them to do with each other, and they thus lose the reputation for exactness and unwillingness to accept anything that is not beyond doubt, which should always characterize science.

A scientific fact, then, claims superiority to all else for two reasons,—the necessary belief in the truthfulness of nature, and the possibility of indefinite repetition of experiments and observations. But when we go beyond the facts and draw inferences, there is primarily no more reason for believing in the truth of the inference from science than in any non-scientific inference. Some conclusions can, by a long and successful verification from the facts of nature, be rendered very certain,—more certain, indeed, than any other factor of knowledge. We, then, frequently call them facts, though they are really nothing more than strong inferences. But this does not in the least give any greater probability to other conclusions. The fact that a theory is a scientific theory tells us nothing as to its probability, for there are many conclusions of theology or morals more probable than certain scientific conclusions. It is only after a conclusion has long stood the test of fact, and has shown itself so in harmony with all nature as to be universally accepted, that there can be claimed for it any of that superior weight of authority which is by general consent given to scientific truths.